Big Idea 4: Interactions

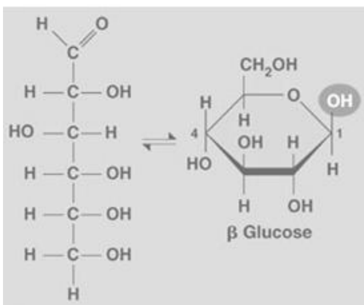
Part A – **Interactions** within biological systems lead to complex properties

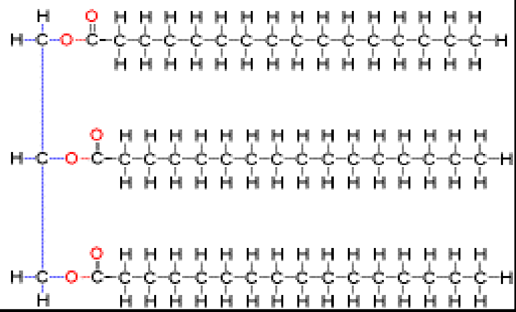
Biological Systems

- Atoms
- Molecules
- Organelles
- Cells
- Organs
- Organ Systems
- Individuals
- Populations
- Communities
- Ecosystems

Molecule Properties

- Atoms interact to form molecules
  - Carbon, Nitrogen, Phosphorous, Oxygen, Hydrogen, Sulfur
- Sequence & location are significant
  - Differences between a carbohydrate & fat





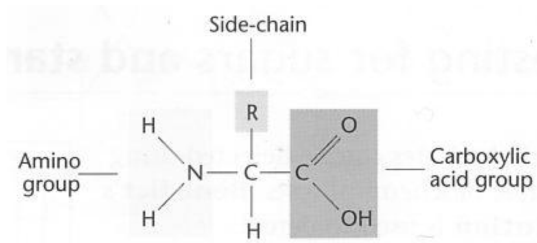
Structure & function depends on monomers & their assembly!

1. Nucleic Acids

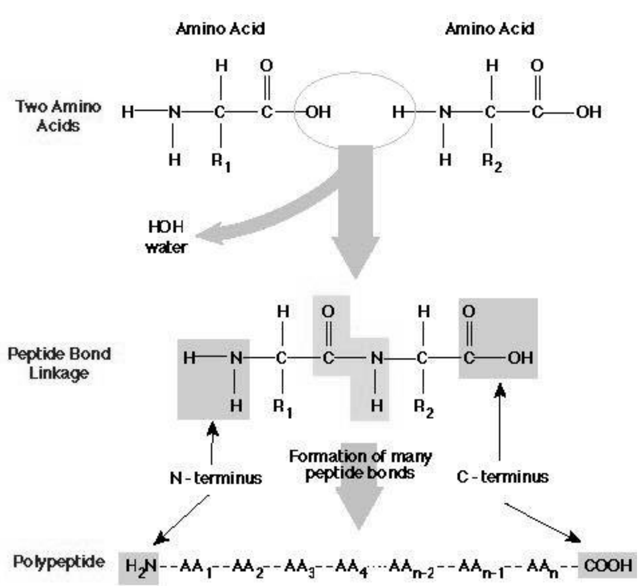
- Nucleic Acid Type
  - RNA vs. DNA?
- Structure suits function
  - RNA vs. DNA?
- Directionality alters function
  - 5' end vs. 3' end?

2. Proteins

- Amino acid interactions depend on structure
  - Hydrophilic, Hydrophobic, Ionic (R-Group)
- Sequence of amino acids leads to different functions & interaction capabilities.



2. Proteins: Directionality – NH_2 vs. COOH ends



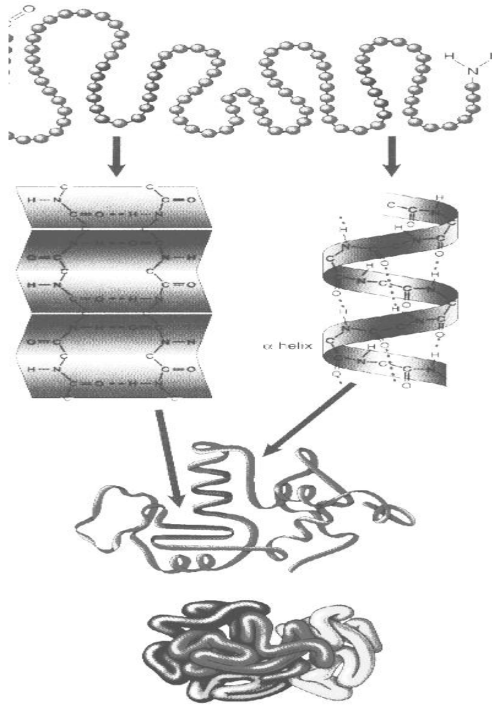
2. Proteins

Primary Structure
- -Peptide bonds
- -Linear sequence of AA's

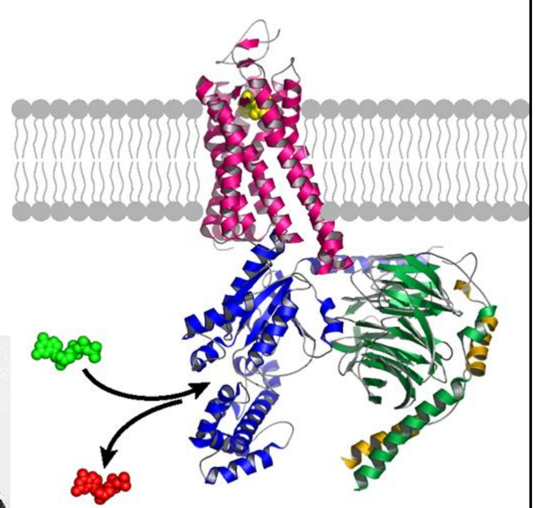
Secondary Structure
- - Hydrogen Bonds
- - Twists & Folds of the sequence

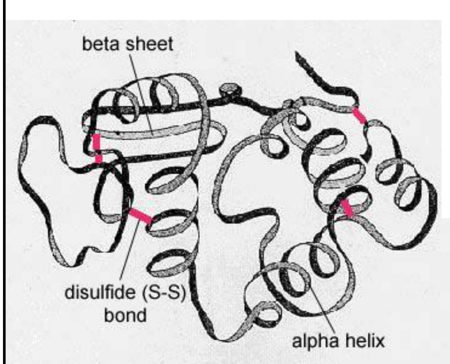
Tertiary Structure
- - R-Group interactions
- - ionic, hydrophobic, etc.

Quaternary Structure
- - 2+ polypeptides interacting



- Sequence leads to specific interactions



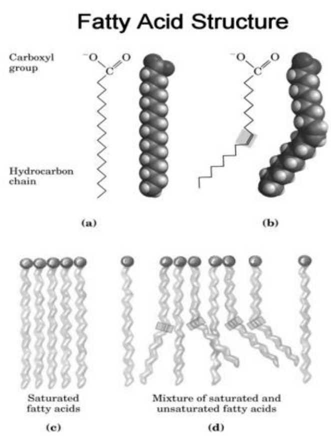


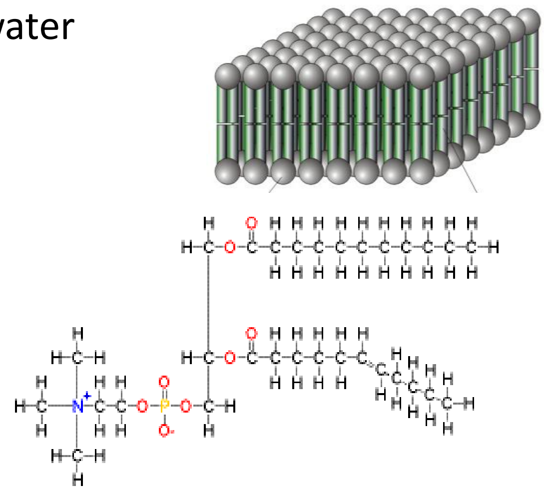
3. Lipids

Non-polar and interact with other non-polars.

Phospholipids have polar regions!

Interact with water

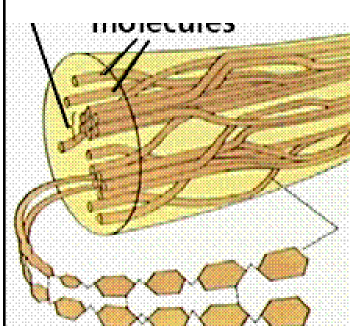


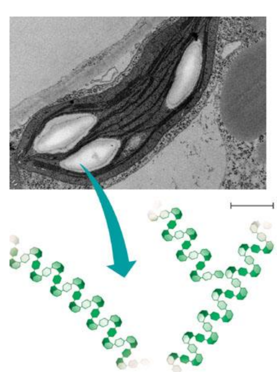


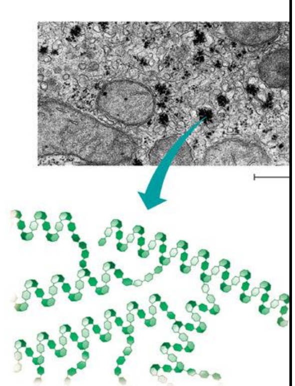
4. Carbohydrates

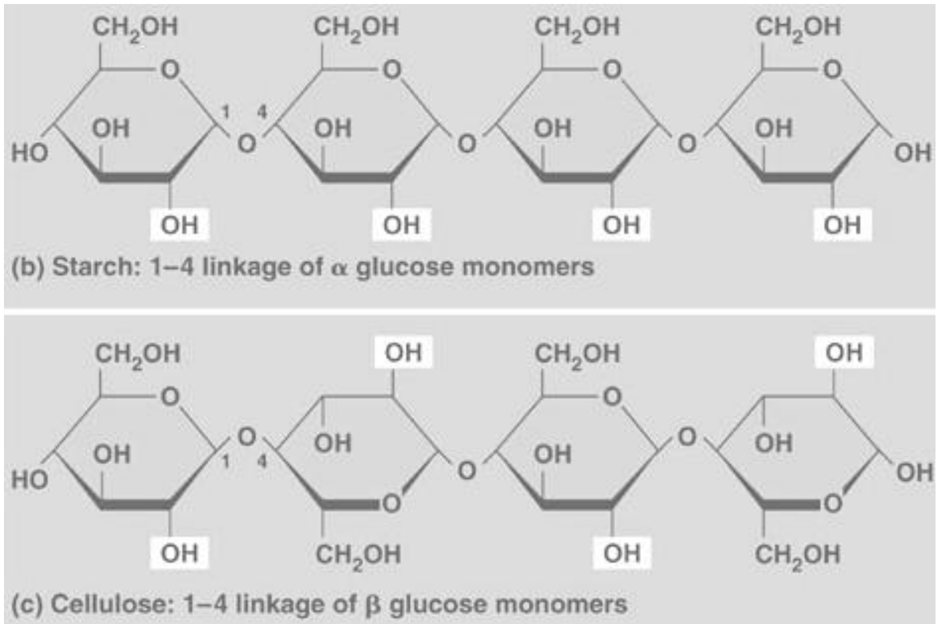
Different monosaccharides & linkages lead to diversity of compounds.

Form also by dehydration synthesis reactions.









- A particular disease results from an amino acid deletion due to a faulty gene. The deleted amino acid has a hydrophobic R-group which usually interacts with a ligand as a fully functional protein. This mutation would most likely result in:
  - A. Faulty DNA structure due to abnormal hydrogen bonding between nitrogen bases.
  - B. Altered secondary structure as a result of abnormal hydrophobic interactions between R-groups in the backbone of the protein.
  - C. Changed properties in the molecule as a result of abnormal interactions between ligand & protein.

Subcellular Components

- The structure & function of subcellular components, and their interactions, provide essential cellular processes.
- Examples:
  - Mitochondria and peroxisomes
  - Mitochondria & Chloroplasts
  - ER & Ribosomes
  - ER & Vacuoles

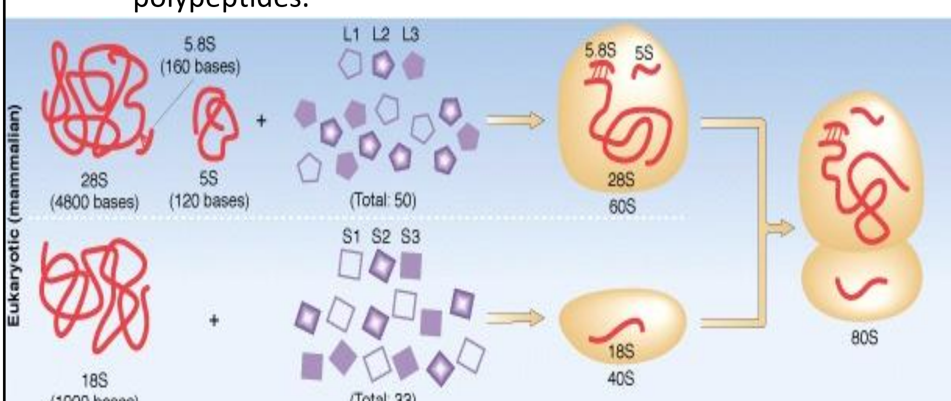
1. Ribosomes

a. Small, universal structures

b. 2 interacting parts: rRNA & Protein

c. Interact to become sites of protein synthesis

d. Translation of genetic information yields specific polypeptides.



1. Ribosomes

   e. Can be “free” or “attached”

   f. **Free** ribosomes are in the cytosol and produce proteins that will **remain** in the cytosol.

   - Glycolysis enzymes – Actin of cytoskeleton

   g. **Attached** ribosomes are embedded in the Rough ER membranes. These protein products will be **secreted** out of the cell OR become **embedded** in the plasma membrane.

   - Sebum of sweat glands
   - Membrane receptor proteins

3. Endoplasmic Reticulum

   a. 2 forms, Rough & Smooth

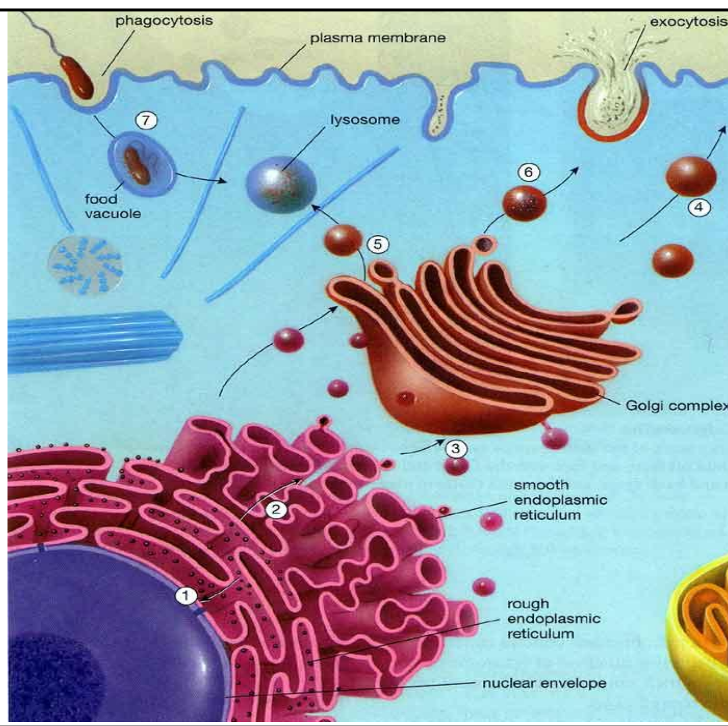
   b. Rough ER:

   1. Compartmentalizes cell
   2. Provides mechanical support
   3. Intracellular Transport
   4. Protein synthesis

   c. Smooth ER:

   1. Synthesizes Lipids

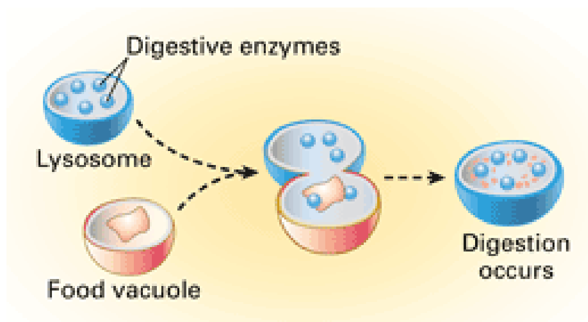
- 4. Golgi Complex
  a. Series of flattened membrane sacs (cisternae)
  b. Synthesize & Package small molecules for transport in vesicles.
  c. Produce Lysosomes.



6. Lysosomes

a. Membranous sacs containing hydrolytic enzymes important for:

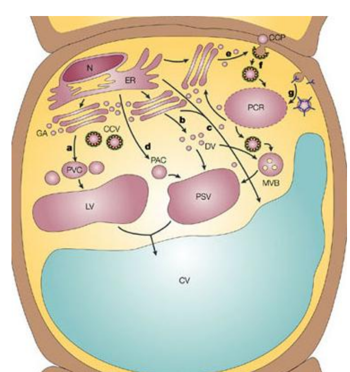
1. Intracellular digestion
2. Apoptosis
3. Recycling of organic materials



7. Vacuoles

a. Membranous sacs
b. Intracellular digestion
c. Release waste products.
d. Plant vacuoles: Variety of functions

1. Pigment storage
2. Cell growth
3. Containing toxins
4. Large SA/V ratio

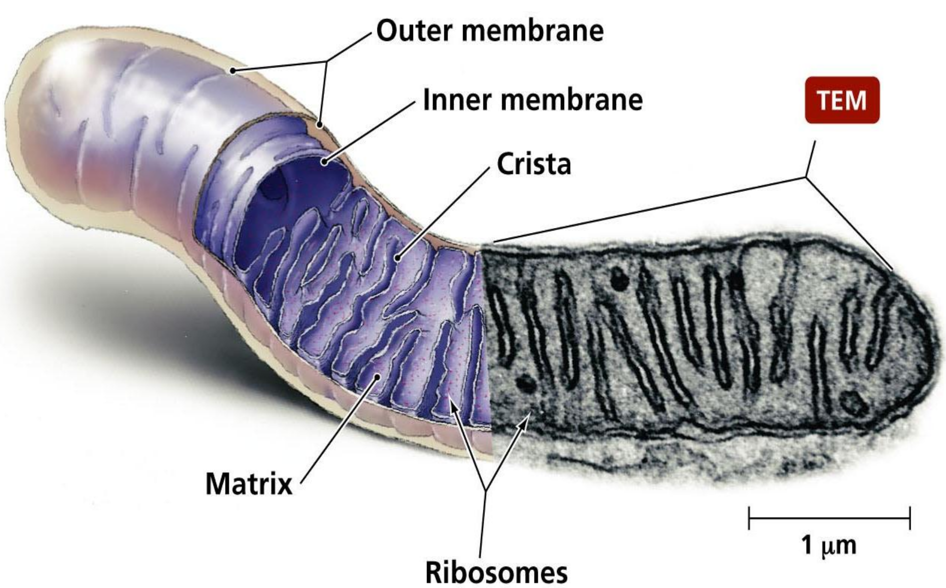


8. Mitochondria

a. Energy capture & transformation

b. Double-membrane allowing for compartmentalization that is inherent to its function.

c. Smooth outer membrane, folded inner membrane (cristae) containing enzymes for ATP production. Folds increase surface area!



9. Chloroplasts

a. Algae & Plants

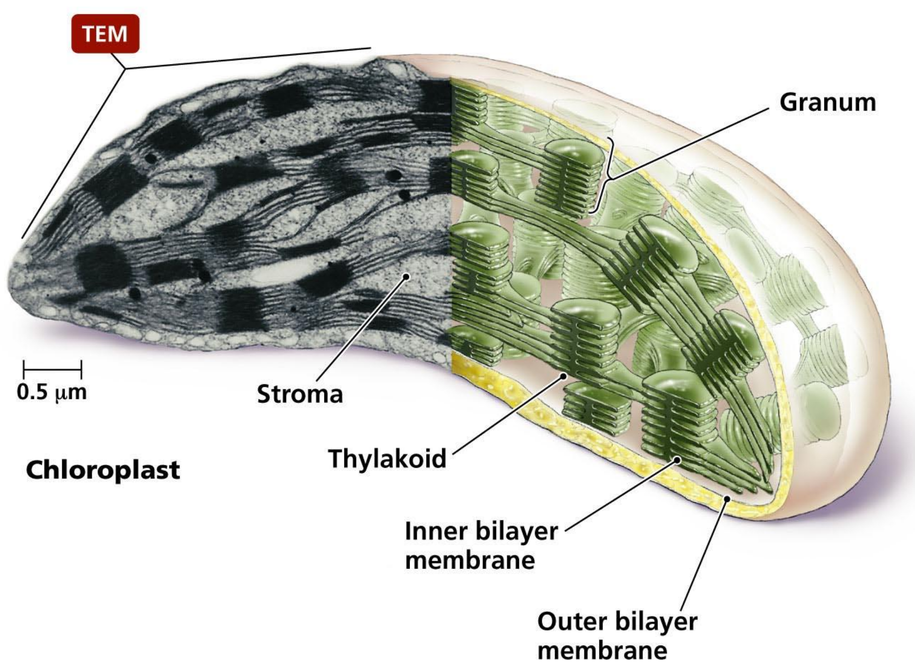
b. Photosynthesis

c. Capture energy in sunlight and convert into chemical bond energy (sugars).

d. A variety of Chlorophylls, but "*a*" primarily

e. Double-membrane compartmentalizes functions.

f. Thylakoids in groups called grana that produce ATP & NADPH, used to power the Calvin Cycle in the stroma, where CO_2 is converted into sugars.



Organ Interactions

- Interactions & coordination between organs provide essential biological activities.
  - Roots, stems, leaves
  - Stomach, small intestine, pancreas

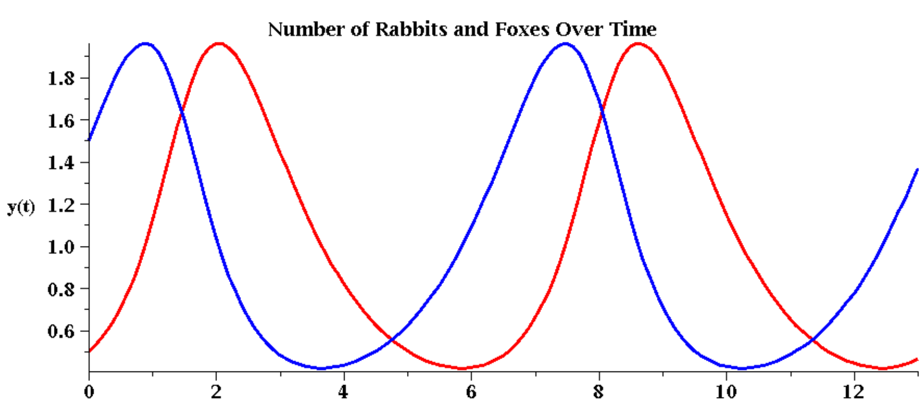
Organ System Interactions

- Interactions between organ systems provide essential biological activities.
  - Respiratory & Circulatory
  - Nervous & Muscular

Populations & Communities

- Communities are composed of populations of organisms that interact in complex ways.
- Community structure is measured and described by its species composition and species diversity.

- Mathematical & Computer models can illustrate & investigate impacts of changes in a population and/or community.
  - Predator/prey spreadsheet models
  - Global climate change models



Population Dynamics

Population: **all the individuals of a species that live together in an area**

Demography: **the statistical study of populations, make predictions about how a population will change**

Population Dynamics

Three Key Features of Populations

- **Size**
- **Density**
- **Dispersion Pattern**
  - **(clumped, uniform, random)**

Three Key Features of Populations

1. Size: number of individuals in an area

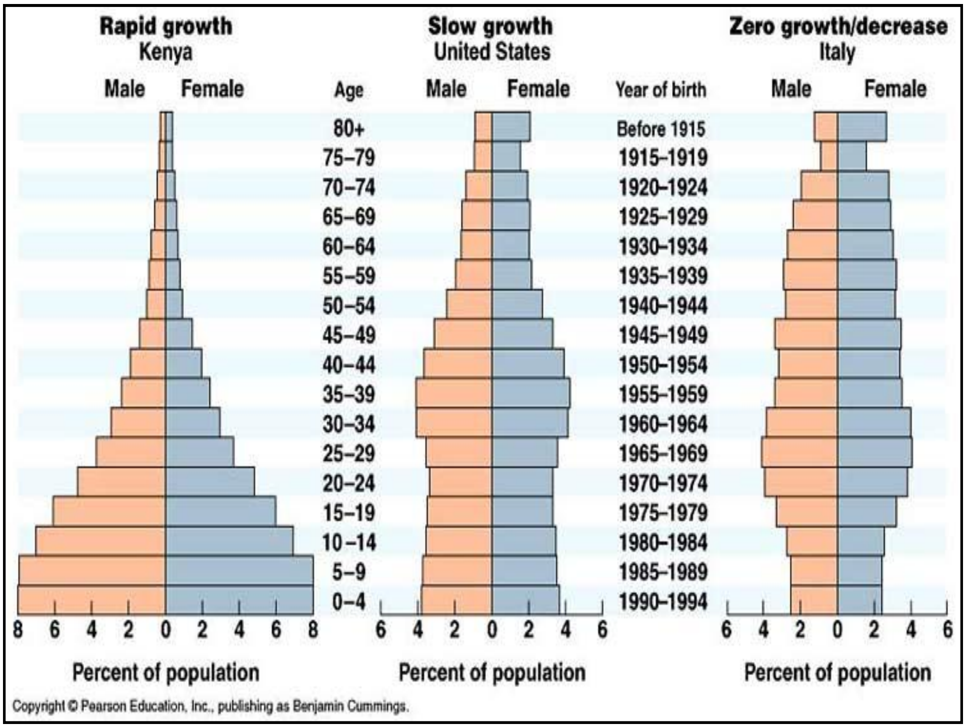
Three Key Features of Populations

Growth Rate: Birth Rate (natality) - Death Rate (mortality)

How many individuals are born vs. how many die

Birth rate (*b*) − death rate (*d*) = rate of natural change (*r*).

$$b - d = r$$

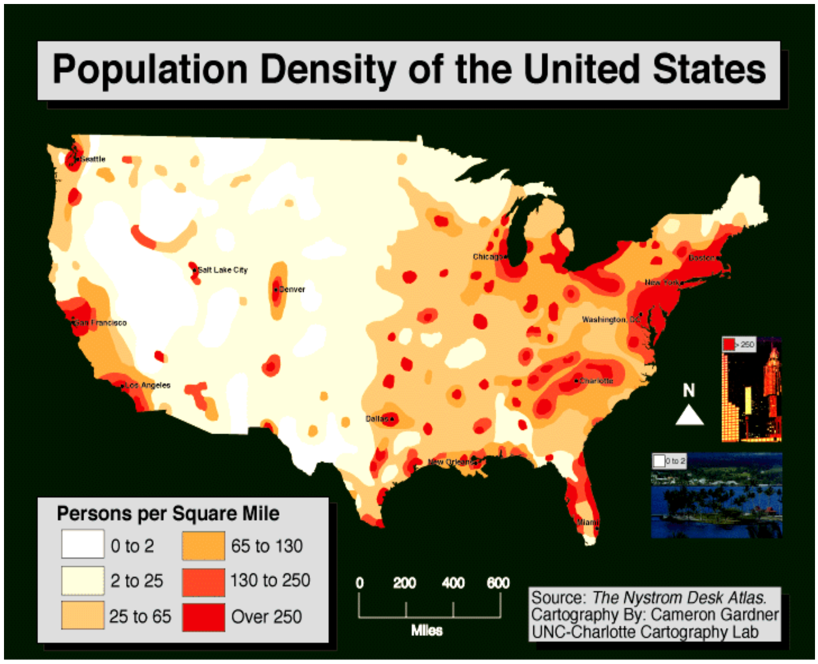


Three Key Features of Populations

2. Density: measurement of population per unit area or unit volume

$$\textbf{Formula: } D_p = \frac{N}{S}$$

Pop. Density = # of individuals ÷ unit of space



4 Factors that affect density

1. **Immigration-** **movement of individuals into a population**

2. **Emigration-** **movement of individuals out of a population**

4 Factors that affect density

3. Density-dependent factors- Biotic factors in the environment that have an increasing effect as population size increases

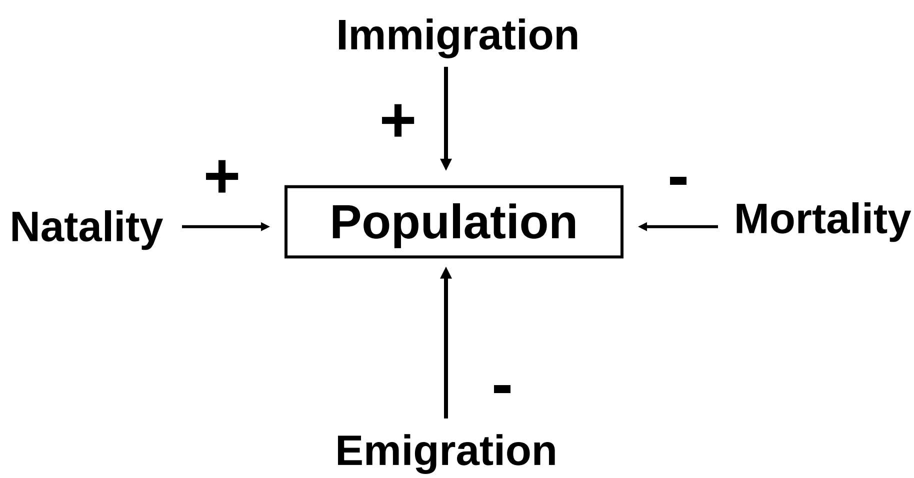
Ex. disease
competition
parasites

4 Factors that affect density

4. Density-independent factors- Abiotic factors in the environment that affect populations regardless of their density

Ex. temperature
storms
habitat destruction
drought

Factors That Affect Future Population Growth

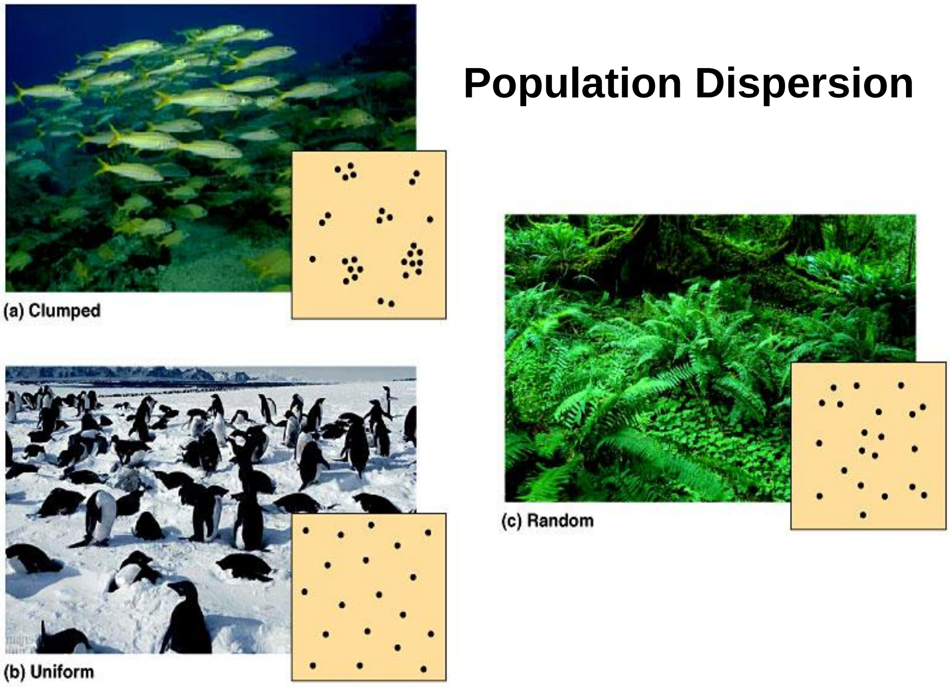


Three Key Features of Populations

3. Dispersion:describes their spacing relative to each other

- **clumped**
- **even or uniform**
- **random**

Population Dispersion

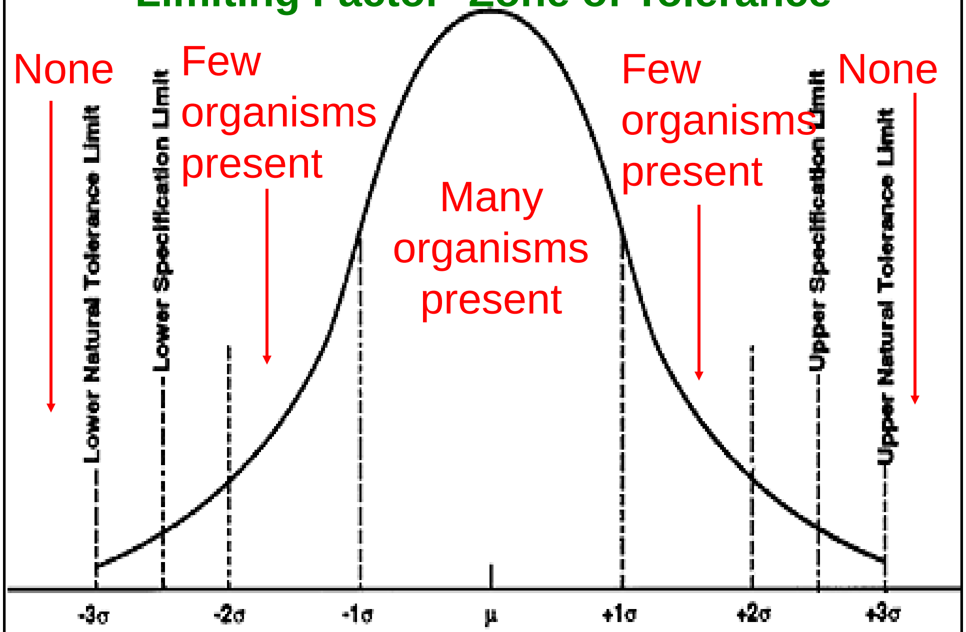


Other factors that affect population growth

Limiting factor- any biotic or abiotic factor that restricts the existence of organisms in a specific environment.

- **EX.-** Amount of water
  Amount of food
  Temperature

Limiting Factor- Zone of Tolerance



Growth Models

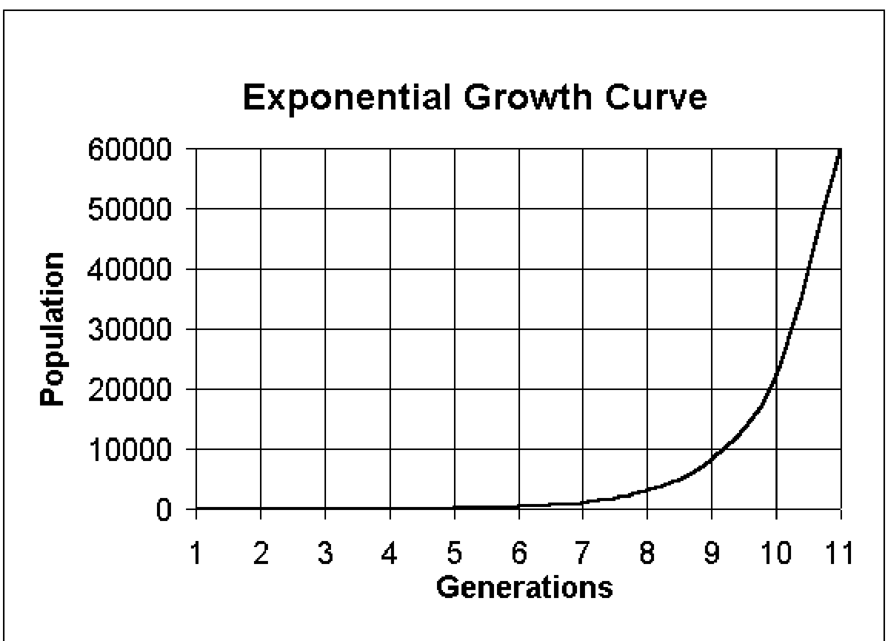
- Exponential Growth – Assumes no limits on resources, no competition, no predation
- Ex. 1 $\Delta N/\Delta t = r_{max}N$
  - Rate of growth (r) = 1

	1	2	3	4	5	6
N	50	100	200	400	800	1600

Growth Models

- Exponential Growth – Assumes no limits on resources, no competition, no predation
- Ex. 2 $\Delta N/\Delta t = r_{max}N$
  - r = 0.5

	1	2	3	4	5	6	7	8	9	10
N	50	75	113	169	253	380	570	855	1283	1924



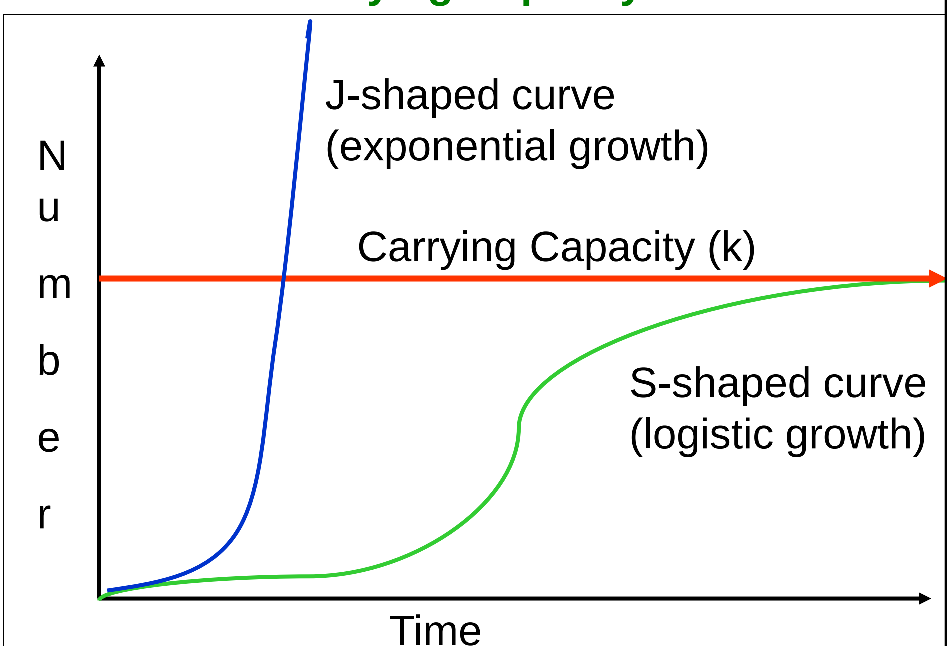
Growth Models

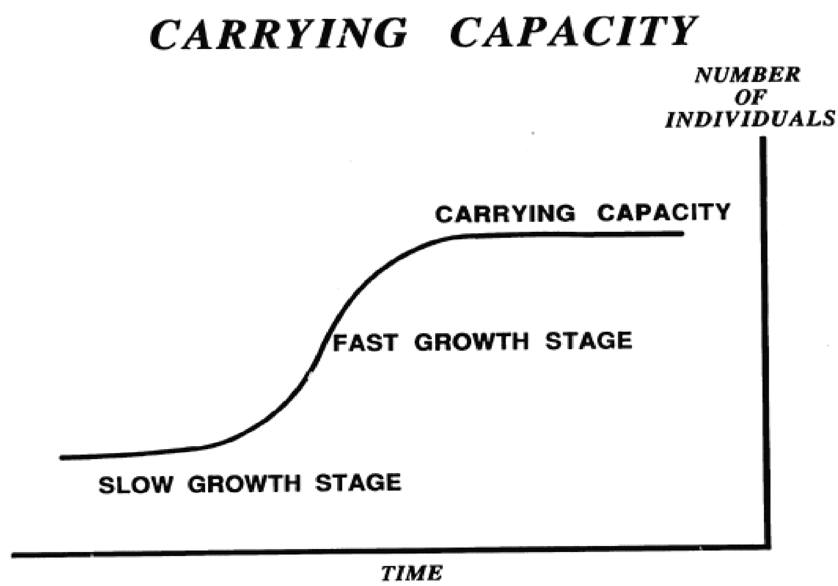
Carrying Capacity- (K) the maximum population size that can be supported by the available resources

There can only be as many organisms as the environmental resources can support

Number varies on environment/species

Carrying Capacity

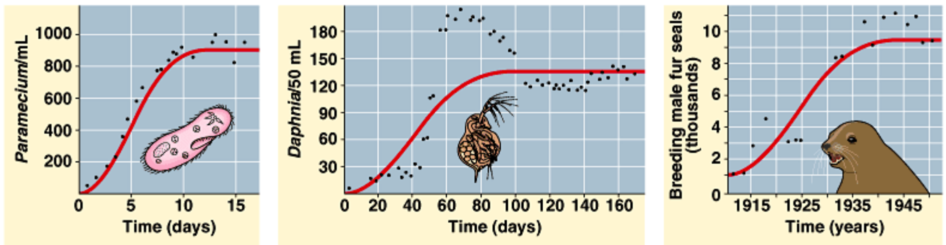




Growth Models

- Logistic Growth: Factors in carrying capacity (K)
- K = 1000

Population Size: N	Intrinsic Rate of Increase: r_{max}	$\left(\frac{K-N}{K}\right)$	Per Capita Growth Rate: $r_{max}\left(\frac{K-N}{K}\right)$	Population Growth Rate:* $r_{max}N\left(\frac{K-N}{K}\right)$
20	0.05	0.98	0.049	+1
100	0.05	0.90	0.045	+5



(a) A *Paramecium* population in laboratory culture

(b) A *Daphnia* population in laboratory culture

(c) A fur seal (*Callorhinus ursinus*) population on St. Paul Island, Alaska

2 Life History Patterns

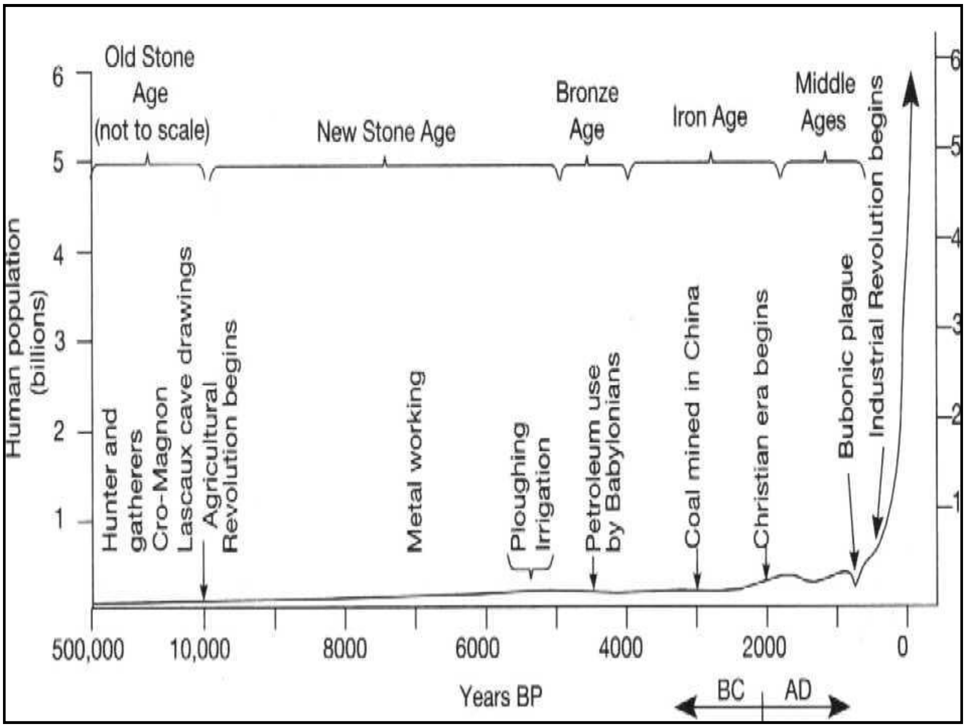
- 1. r-selection
  - short life span
  - small body size
  - reproduce quickly
  - have many young
  - little parental care
  - Ex: cockroaches, weeds, bacteria

2 Life History Patterns

- 2. K-selection
  - long life span
  - large body size
  - reproduce slowly
  - have few young
  - provides parental care
  - Ex: humans, elephants

Human Population Growth

- Do we have a K???
- Yes, but our technology aims to increase it everyday!

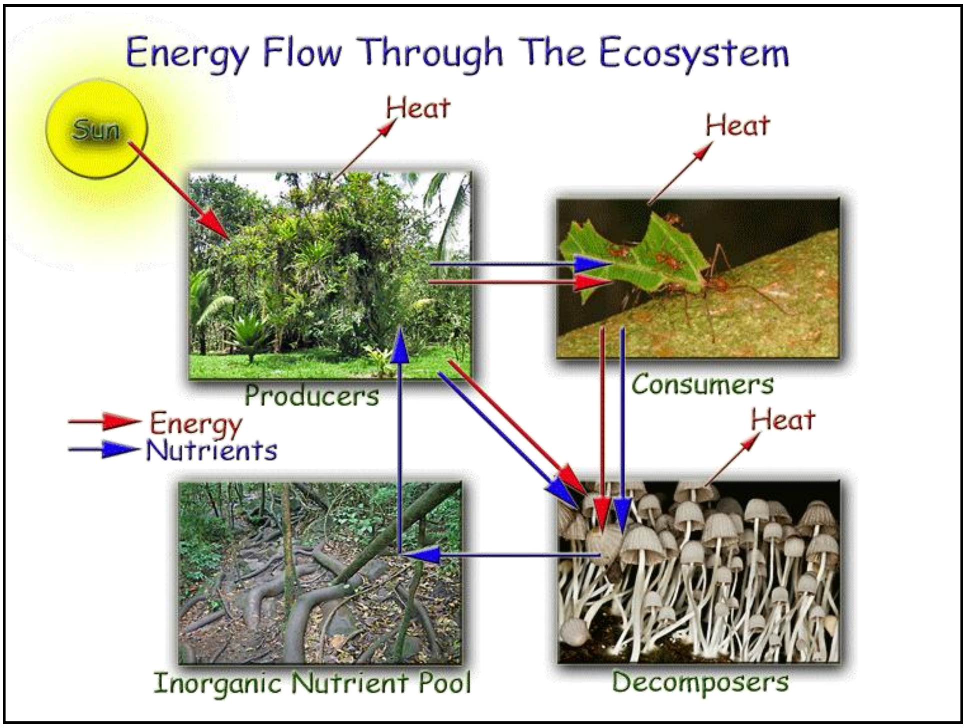


Ecosystems

Interactions between organisms and their environments results in the movement of matter & energy

-***Energy flows through ecosystems***

-Matter is recycled through ecosystems



Primary Production

- Amount of solar energy converted into usable chemical energy in a time period.
- Predicts/Models the health of an ecosystem.
- Any change to primary productivity will lead to an amplified change in the rest of the ecosystem.

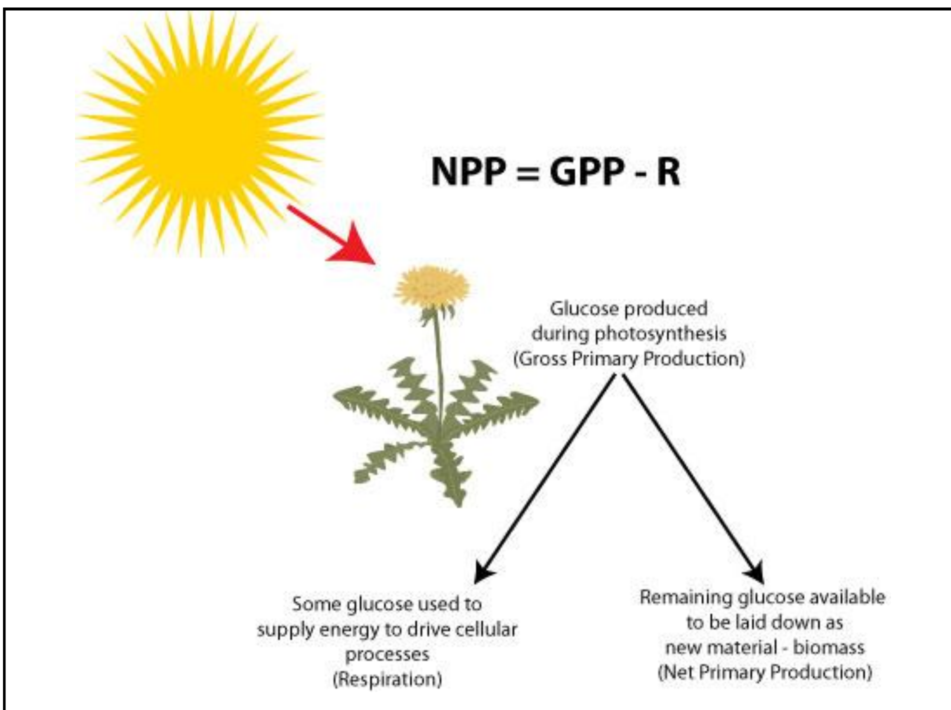
Primary Productivity

Producers: Produce chemical energy but also require it themselves for cellular respiration!

Gross PP = Total chemical energy produced

Net PP = GPP – R

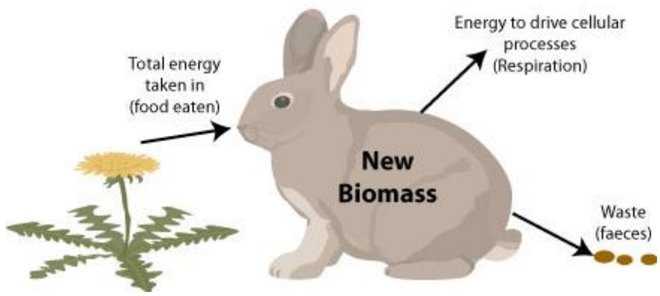
Represents energy available to consumers and can be used to partially predict 'K' for a population



Secondary Production

Amount of consumers' food used towards their own body mass.

Transfers are usually less than 20% efficient.



Energy Transfer

Plant has 200 J energy

Caterpillar eats plant

100 J of plant cannot be metabolized and is elimintated.

67 J is used for cellular respiration

This leaves 33 J (17%) energy contributing to the caterpillars body mass (growth).

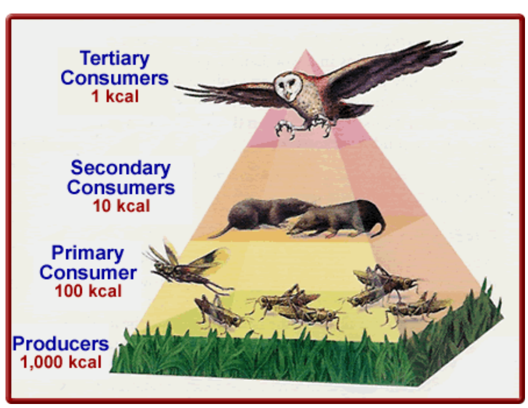
Energy Pyramids

Models used to show energy transfers in ecosystems.

Energy Pyramids

1. Production Pyramid: Shows how much energy is in each trophic level.

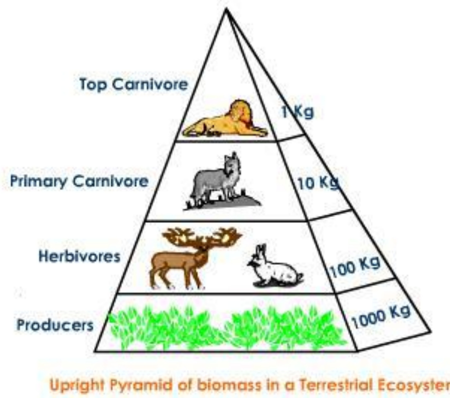
- About **10%** of **energy** in one trophic level is transferred to the next.



Energy Pyramids

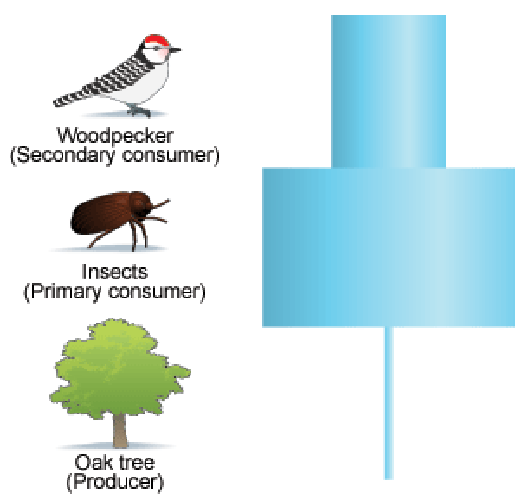
2. Biomass Pyramid: Shows the total amount of living material in a trophic level.

- Represents the potential amount of food for the next trophic level.



Energy Pyramids

3. Pyramid of Numbers: Shows the number of organisms in each trophic level.



Biogeochemical Cycles

- **Transfer matter through the biosphere.**
- **Materials change from one form into another.**
  - **Water Cycle**
  - **Nitrogen Cycle**
  - **Carbon Cycle**
  - **Phosphorous Cycle**

Human Impacts

- As human populations have increased, their impacts on habitats for other species have been magnified.
- As a result, some populations have been reduced in size or driven to extinction.
- Hunting, habitat destruction, air/water quality